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New occurrences of Hoary Fox, *Lycalopex vetulus* (Lund, 1842), and Pantanal Cat, *Leopardus braccatus* (Cope, 1889) (Mammalia, Carnivora), in a Cerrado-Caatinga-Atlantic Forest ecotone in northeastern Brazil

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Abstract

We present new records of Hoary Fox, *Lycalopex vetulus* (Lund, 1842), and Pantanal Cat, *Leopardus braccatus* Cope, 1889, from a Cerrado-Caatinga-Atlantic Forest ecotone, Brazil. Records are based on three roadkilled specimens (two Hoary Foxes and one Pantanal Cat) from Vitória da Conquista, southern Bahia. Although highly anthropized, the region still holds a mosaic of Cerrado savannas and Caatinga seasonally dry forests. Our records expand the distribution of both species eastwards to southern Bahia and suggest that *Leopardus braccatus* may occur marginally in the Caatinga.

Keywords

Bahia state, Canidae, Felidae, range extension, roadkill, road ecology

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Introduction

The Caatinga is the largest seasonally dry forest ecosystem in the Neotropical region, encompassing 912,519 km^2 in northeastern Brazil (Silva et al. 2017). Along its southern limits, the Caatinga intermingles with the Brazilian savanna, the Cerrado, and a small area of the seasonal tropical forest of the Atlantic Rain Forest ecosystem (Silva et al. 2017). This region, encompassing northern Minas Gerais and southern Bahia states, is poorly known and considered a priority area for conservation (Fonseca et al. 2017). With 227 mammal species recorded for the Cerrado (Carmignotto et al. 2012) and 183 in the Caatinga (Carmignotto and Astúa 2017),

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these two ecosystems are not only highly diverse but also have a high proportion of endemic species (Gutiérrez and Marinho-Filho 2017). Additionally, some species of mammals from the Cerrado and Caatinga are shared with the forested formations of both the Amazon and the Atlantic rainforests (Carmignotto et al. 2012).

The Hoary Fox, *Lycalopex vetulus* (Lund, 1842), is one of the smallest South American canids (3–4 kg; Dalponte 2009; Sillero-Zubiri 2009) and one of the few species of the Canidae family with high proportion of insects on its diet (Juarez and Marinho-Filho 2002; Kotviski et al. 2019; Lemos et al. 2020). *Lycalopex vetulus* is considered a typical open-area dweller, occurring along most of the savannic formations in Brazil (Dalponte 2009; Gutiérrez and Marinho-Filho 2017; Lemos et al. 2020). The species has been recently recorded for some Cerrado enclaves within the Caatinga (Pereira and Geise 2009;Olifiers and Delciellos 2013), but it is apparently absent from central and more ecologically typical areas of this ecosystem (Lemos et al. 2020). Despite being classified as a "Near Threatened" species according to its extinction risk in the wild by the IUCN Red List (Lemos et al. 2020), in Brazil Hoary Foxes are considered as "Vulnerable" (Lemos et al. 2013). The species was also recently included in the Brazilian Action Plan for Canid Conservation (ICMBio 2018). Although the Hoary Fox can be locally rare throughout its range, in some regions, such as in southern Minas Gerais and western São Paulo states, the species may be expanding its range, occurring in areas originally covered by the seasonal Atlantic forest that have been transformed by anthropic activities (Fernandes and Costa 2013; Lemos et al. 2020).

The Pantanal cat, *Leopardus braccatus* (Cope, 1889), is a poorly known small felid of approximately 3 kg (Courtenay 2002). Until recently, it was treated as a subspecies of *Leopardus colocola* (Molina, 1782), but molecular and morphological evidence support its status as a distinct species (Nascimento et al. 2020). *Leopardus braccatus* (s.s.) occurs along the diagonal of open formations of South America, from the Chaco of Argentina and Paraguay to the Bolivian lowlands and the Cerrado of central and northeastern Brazil (Garcia-Perea 1994; Nascimento et al. 2020). The species is rarely sighted, and in the Pantanal and Cerrado it occurs in low densities (Queirolo et al. 2013). Due to recent taxonomic changes, *Leopardus braccatus* has not been evaluated by the IUCN Red List, but *Leopardus colocola* is listed as "Near Threatened" according to its extinction risk in the wild (Lucherini et al. 2016). In Brazil, *L. colocola* is considered as "Vulnerable" (Queirolo et al. 2013).

Besides being two typical open-area dwellers, *Lycalopex vetulus* and *Leopardus braccatus* are poorly known carnivores, both with their native habitat highly threatened by the agricultural expansion in Brazil (Queirolo et al. 2013; Lemos et al. 2020). In this sense, records of roadkilled animals are important to understand the present distribution of both species and, if specimens are properly stored in scientific institutions, they may also provide important material for future studies. Here, we report new records for *Lycalopex vetulus* and *Leopardus braccatus* from a Cerrado-Caatinga-Atlantic Forest ecotone in southern Bahia, Brazil, and comment on the biogeographical relevance of the new findings.

Methods

Study area. The BR-116 is a 554 km long highway that crosses part of Bahia, the largest state in northeastern in Brazil (564,733 km^2). Although classified within the Atlantic Forest domain (IBGE 2016), the vegetation in southwestern Bahia, particularly in Vitória da Conquista municipality, is an ecotone among the Atlantic Forest, Cerrado, and Caatinga ecosystems, being an ecological transition area between humid and semi-arid regions (Cole 196; IBGE 2016; Lima et al. 2017). Currently, the Atlantic Forest in southwestern Bahia is fragmented in small patches and has lost its characteristics due to successive anthropic actions, with only 13.5% of the forests remaining (Ribeiro et al. 2009). As a consequence, most of the originally forested areas are now sparsely vegetated open fields. The climate in the region is Af in the Köppen classification and is characterized by a marked dry season, an annual average temperature of 26 °C, and an annual average rainfall of 1,608 mm (Alvares et al. 2013).

The three specimens presented here were roadkilled in the BR-116 highway in Vitória da Conquista municipality. The records are 20 km distant from each other and approximately 30 km north from the Minas Gerais state border (Fig. 1). The region is highly anthropized, composed of small fragments of forest inserted in an exotic pasture matrix (BFSD 2019). The sites are 112 km distant from the nearest Protected Area (Refúgio da Vida Silvestre de Boa Nova).

Roadkill data. The ViaBahia toll road company is responsible for operating and maintaining the highway that crosses the study area. This includes checking along its entire length for stranded vehicles, debris and animal carcasses on the pavement or adjacent to it. For each vertebrate carcass, maintenance personnel are required to register date, time, road number or name, kilometer reference post (100 m accuracy) or Global Positioning System (GPS) coordinates, common or local name of the species in Portuguese, to take a photograph of the dead animal, and to inform the status and fate of the carcass (i.e. if it was disposed or collected). As the maintenance personnel do not have experience in identifying wildlife, all records are validated by an expert to reduce the probability of misidentifications (see Abra et al. 2018). To discuss the range extensions of the new occurrences reported herein, we obtained the updated distribution polygons of *Lycalopex vetulus* (Lemos et al. 2020) and *Leopardus braccatus* (Nascimento et al. 2020).

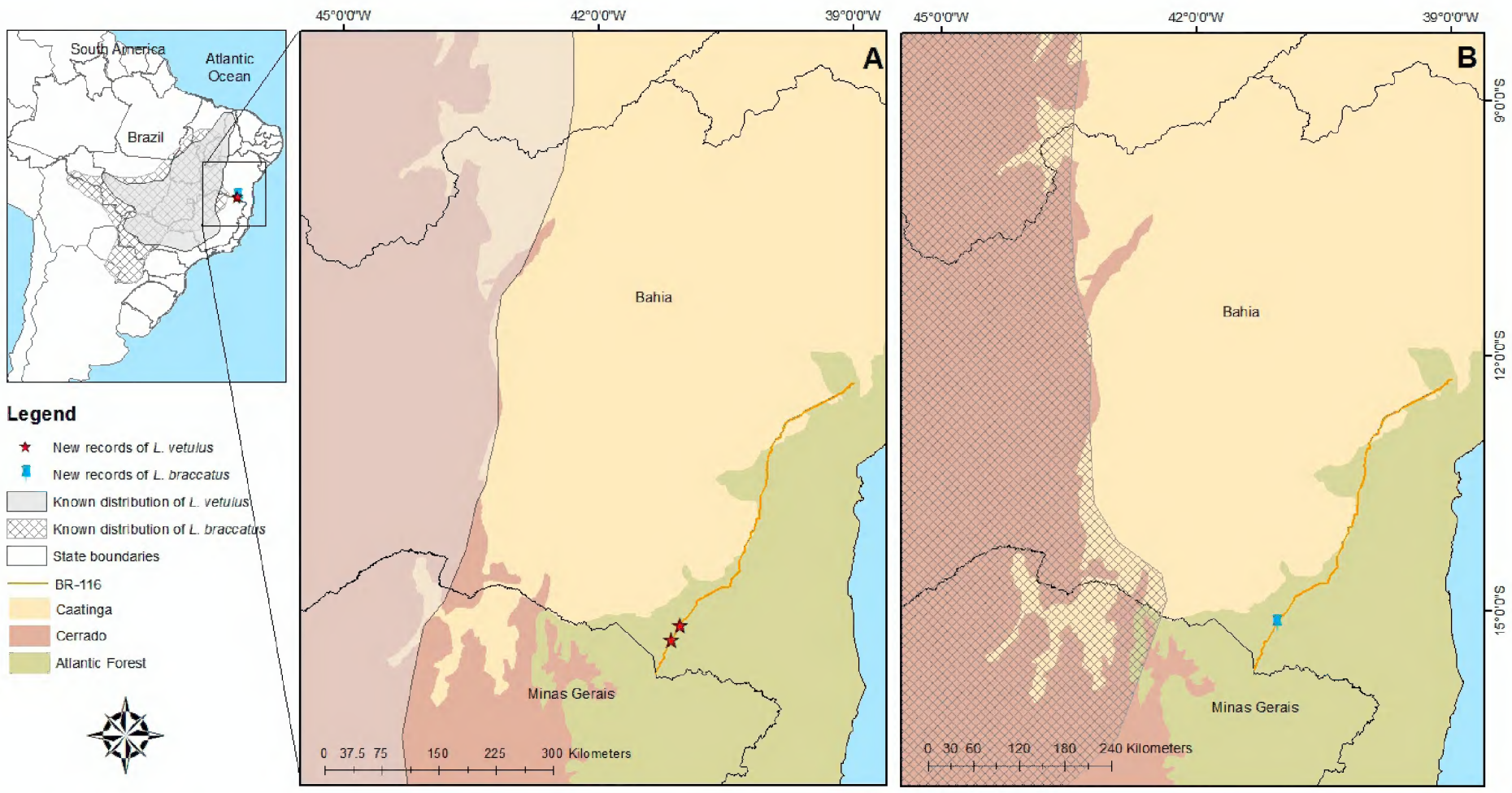

Figure 1. New records (2016 and 2017) based on roadkilled specimens, and the global distributions of (**A**) *Lycalopex vetulus* (based on Lemos et al. 2020) and (**B**) *Leopardus braccatus* (based on Nascimento et al. 2020).

Results

***Lycalopex vetulus* (Lund, 1842).**

New records. BRAZIL • 1 adult of unidentified sex; Bahia, Vitória da Conquista, km 860 BR-116 highway; 15°07′13″S, 041°12′13″W; 13 March 2016 • 1 adult of unidentified sex; Bahia, Vitória da Conquista, km 882 of BR-116 highway; 15°17′59″S, 041°08′31″W; 25 March 2016 (Fig. 1A). Both specimens were roadkilled on the highway and were not collected (Fig. 2A, B).

Identification. This species may be confused with the sympatric Crab-eating Fox, *Cerdocyon thous* (Linnaeus, 1766), as individuals from the Caatinga, known as *C. thous azarae* (Wied- Neuwied, 1824), may have a light-brown pelage similar to *L. vetulus* (Dalponte 2009; Lemos et al. 2013). Hoary Foxes, however, can be differentiated by their smaller size, more gracile head, shorter muzzle, thicker fur, and black mark on the base of the tail, which is absent in *C. thous* (Dalponte 2009, Lemos et al. 2013; Fig. 2A, B).

***Leopardus braccatus* (Cope, 1889)**

New records. BRAZIL • 01 adult ♂; Bahia, Vitória da Conquista, km 863 of BR-116 highway; 15°09′05″S, 041°03′05’’W; 12 August 2017 (Fig. 1B). The roadkilled specimen was collected and is deposited in the Museu de Zoologia da Universidade Federal da Bahia, Salvador, under the voucher number UFBA 645.

Identification. The following external diagnostic characters are observed in Figures 2C, D: brown background color; proximal part of fore and hindlimbs with transversal black stripes; entirely blackish feet; sides of the body with indistinct darker brown lines; tail brown with black tip. The phenotype matches the “Type 3A” and “Group IV” as described respectively by Garcia-Perea (1994) and Nascimento et al. (2020).

Discussion

Basic natural history information on the smaller species of Neotropical carnivores, as *Lycalopex vetulus* and *Leopardus braccatus*, is limited and even the distribution ranges of these two species are imprecisely defined (Sunquist and Sunquist 2002, 2009; Queirolo et al. 2018; Lemos et al. 2020). In this study, we provide new information that extends the southeastern limits of the known range of *L. vetulus* and *L. braccatus* to southern Bahia, reinforcing the hypothesis that both species may occur on Cerrado-Caatinga ecotones.

The closest previous record of *Lycalopex vetulus* is based on observed animals approximately 280 km to the north of the localities reported here (Pereira and Geise 2009). Our record is, therefore, the first photograph-based documentation of *L. vetulus* for southern Bahia and the easternmost locality known for the species. Although previously registered in the Caatinga, records of *L. vetulus* are from habitats of Cerrado enclaves in this ecosystem (Pereira and Geise 2009; Olifiers and Delciellos 2013). Our record also confirms the presence of *Leopardus braccatus* in southern Bahia. Previous records for Bahia are from the western region of the state, and the closest previous record of the species is from northern Minas Gerais, approximately 230 km to the south (Nascimento et al. 2016). This is also the second record of *L. braccatus* east of the Espinhaço Range, a geologic feature that cuts through the states of Minas Gerais and Bahia, latitudinally. The occurrence of *L. braccatus* in the Caatinga is contentious (Nascimento et al. 2016), and while the new record presented here approximates

Figure 2. Three roadkilled specimens along BR-116 highway (Vitória da Conquista, Bahia). **A.** *Lycalopex vetulus* (adult, unknown sex). **B.** *L. vetulus* (adult, unknown sex). **C, D.** *Leopardus braccatus* (adult male), same individual taken from different angles. Photographs by the Via Bahia toll maintenance personnel.

its distributional range to the biome, it is possible that *L. braccatus* may occur only marginally in this ecosystem. Previously published extensive surveys in core areas of the Caatinga, i.e., typical xerophytic habitat, do not indicate the presence of either *Leopardus braccatus* or *Lycalopex vetulus* (Marinho et al. 2018; Campos et al. 2019). Therefore, it is likely that these two open-areas dwellers are absent from the seasonally dry forests of the Caatinga, being restricted to its margins or to savannic enclaves of Cerrado within this ecosystem.

We reinforce the importance of carrying biodiversity surveys and reporting species occurrences from insufficiently surveyed ecosystems, as the Caatinga. In this sense, roadkill data may provide new records of rare and/or poorly known species. We also recommend consulting experts to ascertain the taxonomic identity of roadkilled specimens. This is especially relevant when roadkill data is collected by maintenance personnel, as is usually carried out by Brazilian toll road companies.

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Authors' Contributions

FDA and PRP collected the data, made the maps and figures, and contributed to the writing of the manuscript. GSTG wrote the first version of the paper and made revisions. FGL and FON contributed to the identification of specimens, writing of the manuscript, and insights on species distribution.

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